

Impact of Home-Based Monitoring on the Care of Patients With Congestive Heart Failure

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Congestive heart failure (CHF) affects nearly 5 million people in the United States with an annual cost of \$30 billion. Home-based telemonitoring is a therapeutic tool that may reduce costs and improve patient satisfaction. This article assesses the effectiveness of home telemonitoring in patients with class III or IV CHF recently discharged from the hospital. A cohort of patients (n = 83) were provided home telemonitoring for a 2-month period following hospital discharge. Home visit frequency, patient rehospitalization rate, emergency department use, quality of life, and health care costs were compared to a similar usual care cohort (n = 83). Patients in the telemonitor group transmitted their weight, blood pressure, and oxygen saturation daily to a telemonitor nurse who evaluated each patient with a follow-up telephone call. Daily home care telemonitoring reduced the frequency of home nursing visits, provided cost savings, and was associated with improved self-perceived quality of life.

Prevention, 1994; Lee, Chavez, Baker, & Luce, 2004; Rich, 1997). The increasing prevalence of this condition, due to the aging of the population (American Heart Association, 2004; Rich, 1997) and to improved treatment of acute coronary syndromes, has had a substantial economic impact on our health care system (American Heart Association, 2004; Massie & Shah, 1997). Home health care has traditionally been a cost-effective alternative to hospitalization (Scully, 2003) and many patients with CHF prefer the home setting to the hospital (Harris Interactive, Inc., 2001; Wilson, Wynn, & Parker, 2002). The current manpower shortage in home health care, coupled with ever-increasing labor and administrative costs (Murtaugh, McCall, Moore, & Meadow, 2003), has motivated care providers to evaluate new technologies for home-based care (Office for the Advancement of Telehealth, 2001).

Remote monitoring between a health care provider and a patient in his or her home setting (home telemonitoring) is an emerging technology that has the potential to enable patients with chronic illness such as CHF to remain at home while improving health care access and reducing health care costs (Bondmass, Bolger, Castro, & Avitall,

Congestive heart failure (CHF) has a tremendous impact on patients, the medical system, and society (American Heart Association, 2004; Ansari & Massie, 2003; Centers for Disease Control and

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1999; Brantley, Laney-Cummings, & Spivak, 2004; Department of Health and Human Services, 2001; Heidenreich, Ruggerio, & Massie, 1999; Johnston, Weeler, Deuser, & Sousa, 2000; Nobel & Norman, 2003; Noel, Vogel, Erdos, Cornwall, & Levin, 2004; Roupe & Snowden, 2004). Whereas several prior studies have demonstrated the efficacy of telemonitoring interventions in reducing rehospitalizations, emergency department (ED) visits, and increasing patients' quality of life (Artinian et al., 2003; Benatar, Bondmass, Ghitelman, & Avitall, 2003; Cordisco, Beniaminovitz, Hammond, & Mancini, 1999; Jerant, Azari, & Nesbitt, 2001; Meyer, Kobb, & Ryan, 2002; Rich et al., 1995; Shah, Der, Ruggerio, Heidenreich, & Massie, 1998) there is a contrasting body of literature that questions the benefits and cost savings of home telemonitoring (Hersh, Wallace, & Patterson, 2001; Jennett et al., 2003; Louis, Turner, Gretton, Baksh, & Cleland, 2003; Jerant & Nesbitt, 2005). Many prior studies were limited by small sample size (Bondmass et al., 1999; Cordisco et al., 1999; Jerant et al., 2001; Roupe & Snowden, 2004). Two recent large-scale randomized control trials demonstrated similar hospitalization and use rates and decreased mortality rates in the intervention groups (Cleland, Louis, Rigby, Uwe, & Balk, 2005; Goldberg et al., 2003). These results contrast with a recent large-scale telemonitoring study that demonstrated significant reductions in hospitalization rates and health care costs compared to usual care for patients with CHF (Nobel & Norman, 2003).

Previous studies have revealed that 25% to 50% of patients with CHF are rehospitalized within 3 to 6 months of hospital discharge (Krumholz et al., 1997; Schwarz & Elman, 2003). Reasons for rehospitalization include lack of patient adherence to a prescribed medication or a dietary regimen, lack of patient knowledge about early signs of CHF, lack of planned follow-up with posthospitalization care, and lack of a prescribed standardized therapy. Each of these factors is potentially amenable to a home telemonitoring intervention. Based on these findings, we implemented a home telemonitoring intervention among recently discharged patients with class III or IV CHF that consisted of daily patient self-monitoring and a daily phone call to the patient. We then compared use outcomes to a similar cohort of usual care patients within the same health care system.

MATERIALS AND METHODS

Study Design

We enrolled a cohort of 83 patients in a home telemonitoring program between September 2003 and

February 2005 and compared their medical outcomes to 83 usual care patients. All patients were cared for by Partners Home Care, a home health agency within the integrated delivery system of Partners Health Care, Boston, Massachusetts. The telemonitor group received home monitoring for up to 2 months after hospital discharge and the usual care group received traditional home health care for a similar time period. This study was approved by the Partners Health Care institutional review board and funded by Partners Telemedicine (70%) and the Partners IT Research Council (30%).

Home Telemonitor Patients

Eligibility criteria for study participation included admission to the home care agency, a primary diagnosis of CHF class III or class IV, age over 64 years, English speaking, cognitive ability to learn new material, no more than three associated comorbidities, a working telephone, and a Medicare fee plan. Of approximately 120 patients approached to participate, 96 met study criteria and consented to enroll in the study. Of the 96 initially enrolled patients, 13 did not continue the study beyond 2 weeks and were not included in the study results, leaving 83 patients in the telemonitor group. Reasons for early withdrawal included patient expression of upset or nervous feelings about the monitor (6 patients); technical issues, either user- or monitor-based (3 patients); early rehospitalization (2 patients); and died at home (2 patients).

Usual Care Patients

The usual care group was randomly selected from patients in the same home care agency and the same geographic area as the telemonitor group. Usual care patients were identified based on a primary diagnosis of CHF class III or IV, age, geographic area, date of admission to and discharge from home care, and fee plan. The time period selected for the usual care group historic data was the 6-month period prior to the start of the study (February to July 2003). Patients from both the telemonitor and usual care groups were excluded if they were enrolled in the study for less than 2 weeks' time.

Of the 83 patients included in the telemonitor group, 19 did not complete the study period of 55 to 60 days. Six telemonitor patients died, 1 patient entered hospice, and 1 patient moved out of state. Seven telemonitor patients withdrew from the study because they felt anxious or upset about the telemonitoring. Two patients lost their paid caretaker and could not do the procedure independently and 2 patients were withdrawn by study staff. Of the 2 patients taken off the

study by staff, 1 patient was a double amputee, making it difficult to monitor daily weights. The other patient developed osteomyelitis and required daily home care visits.

In the usual care group, 24 patients were discharged before the end of the 2-month period: Seventeen patients were discharged because “goals were met” (i.e., patients were deemed stable and able to independently monitor their condition), 3 patients were rehospitalized, 1 patient was considered not homebound, 1 patient moved to assisted living, and 1 patient died. All telemonitor ($n = 83$) and usual care ($n = 83$) patients who were monitored for 2 weeks or more were included in the study results.

Home Telemonitoring Equipment

Telemonitoring equipment included American Tele-Care, Inc., (ATI) FDA-approved devices: an NX monitoring station (NX is an internal description meaning “next generation”), a LifeSource digital weight scale, an A&D blood pressure/pulse cuff and meter and a BCI[®] pulse oxymeter device. Once installed in the patient’s home, the NX patient station was part of a secure system that ensured the privacy and integrity of transferred patient information. Patient data were transferred via telephone service to the Internet. The NX patient station was configured with a local Internet service provider (ISP) telephone number, an ISP login ID, and an ISP password that together enabled a secure connection to the Internet. The HTTPS connection used for encryption was by secure sockets layer technology to ensure confidential data transmission.

The Telemonitoring Intervention

A nurse introduced eligible patients to the study during a home visit. For patients interested in study participation, physician orders were obtained and the nurse arranged a home visit the next day to reassess the patient, obtain informed consent, and begin patient/family instruction about the telemonitoring equipment and procedure. Enrolled patients were taught how to take their vital signs and weight and the procedure for sending the readings to the telemonitor nurse. The telemonitor nurse provided additional patient teaching as needed, either by prompting during a daily phone call to the patient or during a home visit.

Patients transmitted monitor readings on a daily basis. Within an hour of receiving the patient’s readings, a nurse telephoned the patient to discuss the results. The skilled nursing portion of the telephone call included evaluation of the telemonitor readings

TABLE 1
Scripted Questions for Daily Assessment
of Telemonitor Patients

Are you feeling better, worse, same?
Is your breathing better, worse, same?
Are your feet/ankles more swollen, less swollen, same?
Is your abdomen more swollen, less swollen, same?
Are you taking your medications?
Has there been any change in your medications?
Do you have your medications?
Have you been adhering to your diet?
Has there been any change in your salt intake?

and a scripted telephone assessment of the patient (see Table 1).

The telemonitor nurse further evaluated patients who experienced clinical signs or symptoms of a worsening condition. Nurse recommendations included increased diuretic dose (if a physician’s order was in place), physician or primary nurse notification, referral to the ED, and continued monitoring.

In addition to daily home telemonitoring, the nurse made a weekly home visit in accordance with the current minimum Medicare requirement for provision of skilled nursing care.

To assess the patients’ perceptions of the physical and psychological effects of telemonitoring during the course of the intervention, telemonitoring patients were given self-administered SF-36 v.2[®] quality-of-life surveys at the initial home visit and again at the time of discharge from the study (Ware, Kosinski, & Gandek, 2000).

DATA ANALYSIS AND STATISTICAL METHOD

Primary study outcomes were number of skilled nursing home visits, number of hospitalizations, number of ED visits, and costs. The average number of home visits per month was determined by dividing the total number of home visits made by the total number of days in home care for all patients and multiplying the quotient by 30 days. *Days of home care* was defined as the number of days a patient was under the care of a home health care provider as recommended by the patient’s physician. The 2-month period of home telemonitoring is the standard length of time that patients with CHF are approved for home skilled nursing services according to Medicare’s prospective payment system.

Cost differences between the telemonitor and the usual care groups were estimated based on the calculated

TABLE 2
Patient Characteristics

<i>Characteristic</i>	<i>Telemonitor Group (n = 83)</i>	<i>Usual Care Group (n = 83)</i>	<i>p Value</i>
Age (years)	79.0 ± 6.9	82.5 ± 5.9	.0005
Female gender	45 (53.3)	48 (57.8)	.64
Medications	10.7 ± 3.6	10.1 ± 3.8	.30
Comorbidities (average)	1.87 (0 to 3)	1.59 (0 to 3)	.09
Days in home care	51 (36 to 56)	38 (25 to 55)	.01

NOTE: Numbers are means ± standard deviations, medians (interquartile ranges), or numbers (percentages). *p* values are from *t* tests, Wilcoxon rank sums, or chi-square tests.

difference in skilled nursing home visits per patient between telemedicine and usual care patients. We subtracted from this total the estimated cost of implementing home telemonitoring for our 83 study participants. For the telemonitoring patients, we conservatively estimated that daily phone calls by the telemonitor nurse lasted 5 minutes per patient, that administration of the project required 2 hours total per week for 83 patients, and that the equipment rental for 2 months was \$198.00 per patient. Because there were no significant differences in number of hospitalizations or ED visits, these costs were not included in our estimates.

Baseline variables and the primary outcomes were compared between the telemonitor and usual care groups using *t* tests for normally distributed continuous variables and chi-square tests for categorical variables. In addition, linear regression models were constructed to control for imbalanced baseline variables when comparing primary outcomes between the two cohorts. Paired *t* tests were used to assess changes from baseline in individual and composite SF-36 scores among the telemonitor patients completing both entry and exit surveys ($n = 50$). All analyses were performed using SAS (SAS v.9, Cary, North Carolina) except for the SF-36 scores (R software; *The R Project*, n.d.).

RESULTS

Baseline patient characteristics are presented in Table 2. Usual care patients were somewhat older (mean age 79.0, *SD* ± 6.9 in the telemonitor group vs. 82.5, *SD* ± 5.9 in the usual care group, $p < .001$). Telemonitor patients were enrolled in home care for an average of 39.8 days but usual care patients were enrolled in home care for an average of 38.2 days ($p = .006$).

Health System Utilization

Patients in the telemonitor group received 5.8 home visits per month compared to 8.2 visits per month for

the usual care group ($p < .0001$, Table 3). The telemonitor group had 18 hospitalizations over 3,307 days of home care enrollment (0.02 hospitalizations per year per patient) but the usual care group had 24 hospitalizations over 3,222 days of home care enrollment (0.03 hospitalizations per year per patient, $p = .21$). Emergency department visits were relatively uncommon and not different between the two groups (7 telemonitor group vs. 6 usual care group, $p = .77$). The cost savings of the telemonitor group was estimated to be \$189.92 per patient in a 2-month monitoring period. Controlling for baseline imbalances in age and total days of home monitoring in multivariate models did not significantly change these results (Table 3).

Quality of Life of Telemonitor Patients

Of the 83 telemonitor patients, 58 completed and returned both entry and exit surveys. Overall scores on the entry and exit quality-of-life surveys were generally low (Table 4). Bodily pain and vitality scores improved significantly.

Medications Prescribed

Types of medications prescribed for patients with CHF showed variation from standardized recommended guidelines. However, the two groups were similar in percentage of medications prescribed except that the home telemonitoring patients were more likely to be prescribed diuretics (92% vs. 89%, $p = .04$; see Table 5).

DISCUSSION

Patients receiving home telemonitoring in our study required significantly fewer home visits compared to the usual care group, and they had no differences in hospitalization or ED encounters. These findings are reassuring that the fewer skilled-nursing home visits in the telemonitoring group did not result in increased

TABLE 3
Health Care Utilization

	<i>Telemonitor Group (n = 83)</i>	<i>Usual Care Group (n = 83)</i>	<i>p Value</i>
Home visits per week (days)	5.8 ± 1.6	8.2 ± 2.40	<.0001
Hospitalizations	0.2 ± 0.5	0.3 ± 0.8	.22
Emergency department visits	0.05 ± 0.2	0.05 ± 0.2	.74
Estimated cost based on number of home visits per patient for 2 months at \$110 per home visit	\$1,276	\$1,804	
Telemonitoring equipment/services per patient for 2 months	\$198		
Telemonitor nurse at \$30.00/hr per patient for 2 months (4.5 hrs.)	\$135		
Nurse administrative costs at \$30/hr per patient for 2 months (based on 2 hrs/week for 83 patients)	\$57.8		
Cost savings per patient for 2 months	\$189.92		

NOTE: Data are normalized for days in home care.

TABLE 4
SF 36 v.2® Telemonitor Group Results (n = 50)

	<i>Entry</i>	<i>Exit</i>	<i>p Value^a</i>
Physical functioning	25.8	31.6	.07
Role physical	27.4	35.2	.05
Bodily pain	39.5	29.3	.00
General health	46.1	49.8	.18
Vitality	39.9	48.8	.00
Social function	44.8	57.3	.01
Role emotional	57.5	65.1	.21
Mental health (MCS)	68.7	75.8	.01

a. *p* values are from paired *t* tests.

TABLE 5
Classification of Prescribed Medications

<i>Prescribed Medication</i>	<i>Telemonitor Group</i>	<i>Usual Care Group</i>	<i>p Value</i>
Diuretic	92%	89%	.04
Beta blocker	60%	61%	.21
ACE inhibitor	41%	35%	.40
Anticoagulant	66%	57%	.38
Digoxin	24%	19%	.45
Antidepressant	10%	12%	.61

adverse events requiring hospital-based care and support the beneficial role of home telemonitoring for patients with class III or IV CHF.

After accounting for the implementation costs of home telemonitoring, this strategy resulted in a net cost savings

as a consequence of fewer skilled nursing home visits. These savings are likely to be even greater when implemented systematically, given the economies of scale likely to be realized in the administration of the program.

Although our study results demonstrated that progress was made in reducing the number of hospitalizations in the telemonitor group (21.8%) compared with the usual care group (28.9%), this result was not statistically significant.

Previous home telemonitoring studies have demonstrated a range of cost savings from significant (Heidenreich et al., 1999; Jerant et al., 2001; Noel et al., 2004) to minimal (Johnston et al., 2000; Meyer et al., 2002) to equivocal (Shah et al., 1998), depending on the study's goals, research design, and variables. For example, using a quasi-experimental design, Johnston et al. (2000) noted a potential for cost savings as a result of increased productivity of telemonitor nurses compared to nurses making traditional home visits. In contrast, Jerant et al. (2001) implemented a 1-year randomized trial and noted a substantial reduction in home care costs as well as hospitalizations and ED visits. Results of the study by Shah et al. (1998) demonstrated a nonsignificant reduction in hospitalizations for patients with cardiovascular diagnoses.

The QOL surveys demonstrated an improved QOL in seven of eight parameters when comparing the entry and exit surveys. Without a comparison to the usual care group, we cannot determine whether this change was directly related to the telemonitoring or to a natural progression of feeling better after an acute-care hospitalization. This finding was reassuring that patients did not fare worse with fewer skilled nursing visits.

Patients in the telemonitor group faced several challenges that included patients' perceptions of technology; patients' abilities to learn new material; and perhaps most important, the value patients and caregivers placed on telemonitoring. There were 13 patients (13.5%) from the original 96 patients who withdrew from the study for reasons of "feeling anxious" or "not liking" the telemonitoring procedure or equipment. Future research efforts should build on these findings to help identify and classify appropriate candidates for home telemonitoring. Other factors to consider in selecting candidates for home telemonitoring include the patient's age, severity of illness, presence of home support, education level, views of technology, and past experiences with technology.

An unanticipated finding was that, regardless of the patients' receptiveness to telemonitoring, there was a need for ongoing teaching of the telemonitoring procedure. In the beginning of the self-monitoring experience, additional telephone prompting and additional home visits were often required to provide reminders concerning the monitoring operation. An increased number of home visits were recorded most often during the early weeks of telemonitoring.

There were several findings of note with respect to medications taken by both the telemonitor and usual care groups. Despite the established effectiveness of beta blockers and angiotensin-converting enzyme inhibitors, there were fewer than expected prescriptions for these drug types to telemonitor and usual care patients. Both drug types have demonstrated an increased life expectancy and a lower rehospitalization rate (Lopez-Sendon et al., 2004) in all New York Heart Association classes of heart disease (Heart Failure Society of America, 2002). Lower prescribing of these drugs may be accounted for by the presence of multiple comorbidities in our study population, contraindications of beta blockers and ACE inhibitors in certain illnesses, and the use of angiotensin receptor blockers.

This study has added to the knowledge of home telemonitoring but several limitations should be emphasized: The nonrandomized design using an historic usual care group may have resulted in bias because of unmeasured confounding. In addition, the QOL data were obtained only in the telemonitoring group and were hampered by modest completion rates (50 of 83, 60%). Barriers to survey completion included rehospitalization, death, withdrawal from the study, or failure to mail back or collect the survey. Many patients needed assistance to complete the survey because of physical or emotional barriers.

Finally, this study does not differentiate the impact of telemonitoring from that of the daily nurse phone call on the reduced requirement for weekly nurse visits.

CONCLUSIONS

The chief finding of this study is that statistically significantly fewer home nursing visits to classes III and IV patients with CHF are needed when daily telemonitoring services are in place as compared with a usual care group. Rehospitalization and ED-visit rates were not statistically different in the two groups. Patients in the telemonitoring group experienced modest improvement in SF-36 scores from the beginning of the study to discharge.

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